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Aquatic invertebrate abundance in relation to changing marsh conditions

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TABLE OF CONTENTS

INTRODUCTION

The importance of aquatic invertebrates as preferred waterfowl foods during the breeding season has been established only recently (Chura, 1961; Perret, 1962; Collias and Collias, 1963; Bartonek and Hickey, 1969; Dirschl, 1969; McKnight and Low, 1969; Swanson and Nelson, 1970). However, the abundance of potential invertebrate foods in different marsh habitats is not well understood. Several studies have quantified the abundance of aquatic invertebrates (Krecker, 1939; Andrews and Hasler, 1944; Gerking, 1957; Chura, 1961; Perret, 1962; Collias and Collias, 1963; Bartonek and Hickey, 1969; Arner, Norwood, and Teels, 1970; Krull, 1970), but only Perret (1962), Bartonek and Hickey (1969), and Krull (1970) summarized data collected during the peak of the nesting season in June. Also, most workers have sampled only within single-species stands of submerged vegetation.

In the present study, invertebrate abundance was measured in selected marsh habitats during June to evaluate different habitats as sources of invertebrate foods for waterfowl during the peak of laying and incubation. Invertebrate populations were monitored from 1968 to 1972 and sampled systematically during 1971 and 1972 to study changes in invertebrate abundance that accompanied changing marsh conditions.

STUDY AREAS

This study was conducted in four prairie marshes in northwestern Iowa near Ruthven. The vegetation of this general area has been summarized by Hayden (1943). Selection for study was based on length of time since the wetland had gone dry and had been revegetated. The marshes shared similar vegetative and limnological characteristics and were classified as slightly brackish, semi-permanent wetlands (Class IV-B) (after Stewart and Kantrud, 1971). However, I modified the cover classes and ecological phases used by Stewart and Kantrud (1971) (Table 1) because finer subdivisions were needed

Table 1. Description of ecological phases of semi-permanent wetlands (modified from Stewart and Kantrud, 1971)

Phase	Description of vegetation
Drawdown phase	Persistance of tolerant species and establishment of seedlings.
Emergent phase	Emergent plants very dense or with some openings. Free-floating plants reduced or absent where emergent plants most dense but colonize and reach maximum abundance in more open situations. Submergent plants become established.
Open emergent phase	Only scattered emergent plants. Free-floating plants decline rapidly from maximum abundance. Submergent plants increase.
Open submergent phase	Submergent plants at maximum abundance and start to decline.
Open water phase	Few or no plants present except where they are sheltered from the wind. Sometimes emergent and/or submergent vegetation will colonize this phase.

to describe the vegetation of discrete areas within marshes. These ecological phases divide the continuous variable of vegetation change into units for easier reference.

In each marsh, several vegetational zones were selected as permanent sampling areas. These sampling areas will be referred to by letters representing an abbreviation of the marsh name and a number signifying the different areas sampled.

Dewey's Pasture

A pothole was chosen for study from a complex network of interconnected marshes which together with several low prairie knolls make up this state wildlife management area. This pothole (referred to as "A-6" by M. W. Weller, unpublished data) had gone dry during 1968, was extensively revegetated, and was being opened rapidly by high water and muskrat (Ondatra zibethica) activity. The sampling areas were:

DP1--Emergent phase in very shallow water. Very dense sedges (Carex spp.) were the predominant plants present in 1971. Floating plants began to colonize the area in 1972.

DP2--Intermediate area of mixed sedges and deep marsh emergents which was not sampled regularly and was not included in this study.

DP3--Emergent phase in deep water. Important plants were cattail (Typha spp.) and bladderwort (Utricularia vulgaris). In 1972, the area reached the open emergent phase.

DP4--Open water phase in deep water until colonized by submerged bladderwort and water milfoil (Myriophyllum spicatum) in 1972. The area was protected from wind action by surrounding emergent vegetation.

DP5--Emergent phase in shallow water. The stand of cattail was removed almost entirely by muskrats during late 1970, but slender riccia (Riccia fluitans) and star duckweed (Lemma trisulca) remained very common because surrounding cattail protected the area from the wind. The area was classified as open emergent phase in 1972 when the coverage by free-floating plants decreased and coverage by submerged plants increased.

DP6--Emergent phase in shallow water with cattail and much free-floating slender riccia and star duckweed.

Dan Green Slough

Dan Green Slough is a 115-hectare (285-acre) marsh that was nearly dry during 1968. It was revegetated at that time, and the emergent vegetation was lost during the course of this study. Sampling areas in different vegetation zones were:

DG1--Emergent phase in very shallow water. Important plants included cattail, lesser duckweed (Lemna minor), and giant duckweed (Spirodela polyrhiza). This zone was dry in 1972.

DG2--Open emergent phase in shallow water. It was vegetated originally with softstem bulrush (Scirpus validus) and sedges. By 1971, duckweeds and bladderwort were the most abundant plants.

DG3--Emergent phase in deep water with cattail, duckweeds, and bladderwort. In 1972, the area was in open emergent phase.

DG4--Open submergent phase in deep water. The principal vegetation was submerged coontail (*Ceratophyllum demersum*). This sampling area was colonized also by river bulrush (*Scirpus fluviatilis*) during the 1968 drought, but almost all the river bulrush was killed by high water within three years.

Trumbull Lake

Sampling areas were established in a 10.4-hectare (26-acre) shallow bay of Trumbull Lake. Both water level and vegetation were stable for several years before and during this study. The sampling areas studied were:

T1--Emergent phase in shallow water with cattail and duckweeds.

T2--Open submergent phase in deep water with a diffuse bed of clasping-leaf pondweed (*Potamogeton Richardsonii*).

Rush Lake

Rush Lake is a 186-hectare (460-acre) marsh which remained flooded during the 1968 drought. It was drawn-down to stimulate revegetation during May, 1971. Seedlings were established on the exposed mud flats during June, 1971, but were removed by floatation following a very rapid rise in water level in early July. Water was removed again in 1972. The areas were:

R1--Drawdown phase where a stand of mature cattail remained in moist soil.

R2--Drawdown phase mud flat with seedling softstem bulrush and cattail.

R3--Open water phase that remained inundated and unvegetated during the drawdown.

METHODS

In each sampling area of the four marshes studied, two sampling sites were chosen randomly and permanently marked. Samples of vegetation, free-swimming invertebrates, and benthos were taken within 5 meters of the marking pole during the first week of June, 1971, and during the last week of June in 1971 and 1972. In addition, preliminary samples were taken at some sampling sites with different methods in 1970 and at Rush Lake and Dan Green Slough during a related project in 1968 and 1969 (Voigts, 1970).

At each sampling site, the vegetation was measured along a permanently established 5-meter transect which was divided into 25-cm segments. Along 10 segments selected at random, a 25 x 25 cm quadrat was used to estimate coverage (after Daubenmire, 1959). Data from the 10 quadrats of both sampling sites were averaged for each sampling area.

Free-swimming invertebrates were sampled with a .1 m^2 dip net which was modified by bending the net frame 45 degrees up from the normal horizontal position. With this modification, when the net rested flat on the marsh bottom, the handle projected up at a 45-degree angle. A sample was taken by lowering the net slowly to the bottom, moving it away from the area disturbed, and raising it straight up. In this way, a semi-quantitative sample of invertebrates per .1 m^2 column of water was obtained. When samples were taken in very shallow water, a straight net was used because the opening of the net could reach from the surface to the bottom. These samples were taken with a lateral motion. Three dip net samples were taken during each visit to a sampling site.

The time needed to empty the net was shortened by fastening a 35 x 50 cm cheesecloth bag inside the net frame with paper clamps. After each sample, the clamps were removed, and the liner was placed in a plastic bag for transport to the laboratory. Each liner then was washed thoroughly to remove all clinging invertebrates. The sample was washed in a No. 30 U. S. Standard Sieve and preserved in 10% formalin.

Benthic invertebrates were sampled with a 30 cm^2 plexiglass core. This small size was necessary because of the great force needed to cut through rootstalks and dead vegetation. Three core samples were taken at each sampling site. Samples were washed through a screened bucket to remove most of the mud and were transported in plastic bags to the lab where they were preserved in 10% formalin.

Hand sorting of preserved invertebrates from the vegetation was exceedingly laborious, but it was the only method that gave reliable results. The procedure for free-swimming invertebrates was speeded by a subsampling method developed at the Northern Prairie Research Center, Jamestown, North Dakota (G. S. Swanson, personal communication, 1971). The sorting pan was divided into a grid of 100 rectangles. Very common taxa were counted in 10 rectangles chosen at random and the total number estimated from this 10% subsample.

RESULTS

Patterns of Vegetative Abundance

Emergent vegetation was most abundant in areas with shallow water (DP1, DP6, DG1, R1, and T1) and in two deep water areas where cattail persisted (DP3 and DG3) in 1971 (Table 2). Coverage by emergent vegetation decreased in most of these areas between 1971 and 1972 as a result of muskrat activities and the effects of high water.

Emergent phase areas in shallow water had the most floating dead vegetation during 1971, and coverage increased in 1972 as a result of the removal of emergent cover by muskrats (Table 2). Although both sampling areas with emergent phase vegetation in deep water (DP3 and DG3) also lost large amounts of emergent vegtation, there was a decline in the coverage of floating dead vegetation at one of the areas sampled (DP3). The reduced emergent vegetation at the DP3 sampling site did not protect the floating dead vegetation and it drifted away. The large amount of floating dead vegetation in the DP5 study area in 1971 was a result of muskrat activity during the preceding winter. Much of this dead vegetation was gone by 1972.

The abundance of free-floating vegetation in different sampling areas also was influenced by the amount of emergent vegetation. Free-floating plants were absent in the DP1 study area in 1971 (Table 2) when the very dense sedges severely limited the light reaching them. Free-floating plants were blown away from sampling areas where emergent plants were too sparse to provide protection (DP4, DG4, T2, and R3). They did remain at

Table 2. Average percent coverage of vegetation during late June

Plant taxa	Phase[a] Year	DP1 E 71	DP1 E 72	DP3 E 71	DP3 OE 72	DP4 OW 71	DP4 OS 72	DP5 E 71	DP5 OE 72	DP6 E 71	DP6 E 72	DG1 E 71
<u>Carex</u> spp.[b]		88	53	0	0	0	0	0	0	1	5	24
<u>Typha</u> spp.[c]		4	0	50	5	2	0	1	0	28	16	93
Total emerg.		92	53	50	5	2	0	1	0	29	21	100
Dead veg.		82	90	35	8	3	0	38	11	73	88	48
<u>L. minor</u>/ <u>S. polyrhiza</u>[d]		0	1	2	1	0	0	1	1	0	1	74
<u>L. trisulca</u>/ <u>R. fluitans</u>[e]		2	78	23	22	1	1	70	26	91	91	8
Total floating		2	79	25	23	1	1	71	27	91	92	82
<u>U. vulgaris</u>		1	3	44	75	2	59	35	69	2	1	0
<u>M. spicatum</u>		0	0	0	2	0	45	0	0	0	0	0
<u>C. demersum</u>		0	0	0	0	0	0	0	0	0	0	0
<u>P. Richardsonii</u>		0	0	0	0	0	0	0	0	0	0	0
Total submerg.		1	3	44	77	2	100	35	69	2	1	0

[a] E, emergent phase; OE, open emergent phase; OS, open submergent phase; OW, open water phase; D, drawdown phase.

[b] Includes small amounts of <u>Scolochloa festucacea</u>, <u>Eleocharis</u> spp., <u>Sparganium eurycarpum</u>, and <u>Iris virginica</u>.

[c] Includes small amounts of <u>Scirpus validus</u>, <u>Scirpus fluviatilis</u>, and <u>Sagittaria latifolia</u>.

[d] Includes a small amount of <u>Wolffia columbiana</u> in 1972.

[e] Includes small amounts of <u>Ricciocarpus natans</u>.

Area sampled													
DG2		DG3		DG4		T1	T2	R1		R2		R3	
OE	OE	E	OE	OS	OS	E	S	D	D	D	D		
71	72	71	72	71	72	71	71	71	72	71	72	71	72
6	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	60	9	1	0	24	0	28	23	17	63	0	0
8	1	60	9	1	0	24	0	28	23	17	63	0	0
17	1	28	49	0	0	82	0	--	--	8	0	0	0
100	11	100	100	0	0	100	0	--	--	0	0	0	0
52	0	2	0	0	0	1	0	--	--	0	0	0	0
100	11	100	100	0	0	100	0	--	--	0	0	0	0
69	66	51	26	1	0	0	0	--	--	0	0	0	0
0	0	0	0	0	0	0	0	--	--	0	0	0	0
0	14	0	7	95	94	0	0	--	--	0	0	0	0
0	0	0	0	0	0	0	62	--	--	0	0	0	0
69	80	51	33	96	94	0	62	--	--	0	0	0	0

sampling area DP5 during 1971 in the absence of emergent cover because the cattail which surrounded the sampling area provided protection.

Coverage by floating vegetation was greater at the shallow DP1 sampling area in 1972 after some of the very dense emergent vegetation was lost, and coverage was less at the DG2 sampling area where the emergent vegetation was almost entirely removed by the effects of high water.

Submerged plants were absent in sampling areas with dense emergent cover (DP1, DP6, DG1, and T1), but they colonized most areas where the emergent vegetation had been partially removed by high water or muskrats (Table 2). Colonization was accomplished within a year in some sampling areas (DP3, DG2), but it took somewhat longer in others (DP5, DG3). Submerged vegetation took several years to colonize sampling area DP4 which was not colonized by any plants during the drought of 1968, and it remained in the open water phase until 1972.

Open submergent phase areas present in 1968 at Rush Lake gradually lost submergent vegetation, and all were classified as open water phase in 1971.

This trend of vegetation loss in large, unprotected open submergent phase areas may have begun during 1972 at the DG4 study area. Examination of the submerged coontail revealed a severe loss of vigor although the coverage remained unchanged (Table 2). Robel (1962) also recorded a loss of vigor and reduction in coverage by submerged plants (primarily sago pondweed, Potamogeton pectinatus) growing in more than 16 inches of water.

Patterns of Phytomacrofauna Abundance

The number of taxa present in the sampling areas ranged from 20 to 32 with few exceptions. The R3 sampling area never had free-swimming invertebrates present, and none were sampled when the R2 sampling area was flooded with 2 cm of water in late June, 1972. The other sampling areas with few taxa were T2 (9 taxa) and DP4 (12 taxa) in early June, 1971. The largest number of taxa recorded was 43 from the DG2 sampling area in early June, 1971.

Although the number of taxa in most habitats was not very different, there was considerable variation in the abundance of free-swimming invertebrates in different sampling areas and on different sampling dates (Appendix A). To study these differences, data from several abundant taxa were selected for analysis. Emphasis was given to samples taken in late June because populations were generally larger and the vegetation was more mature. Data for this analysis was transformed by using the square root of the data plus 3/8 to equalize the variance so statistical tests could be performed.

Isopoda

Isopods (predominantly *Asellus* spp.) were most common in the emergent phase of the Dewey's Pasture pothole where there was much floating dead vegetation in shallow water (Table 3), and numbers tended to decline as the vegetative cover decreased between 1971 and 1972. Abundance increased as the emergent cover increased between early and late June.

Table 3. Late June phytomacrofauna abundance per .1 m^2. (Data were transformed by taking the square-root of the data plus 3/8 to equalize the variance. The F-test of variability between sampling areas used sampling site means)

Sampling areas	Isopoda 1971	Isopoda 1972	Physidae 1971	Physidae 1972	Planorbidae 1971	Planorbidae 1972	Amphipoda 1971	Amphipoda 1972	Chironomidae 1971	Chironomidae 1972	Cladocera 1971	Cladocera 1972	Copepoda 1971	Copepoda 1972
DP1	13.4**	5.2	5.3	8.1	6.6	5.1	7.1**	13.5	3.1	5.7	2.6	1.0	3.1	.9
DP3	5.4	3.8	3.3	4.2	3.0	2.1	9.0**	17.7	4.1	6.6	3.7	1.9	7.2	4.4
DP4	.8	1.3	2.6	3.1	1.4	3.3	5.5*	11.4	3.4**	18.3	9.9	5.0	17.8**	5.1
DP5	9.7**	2.3	8.4*	3.9	8.7	5.4	13.1*	21.0	5.0**	12.2	1.0	3.0	3.4	3.3
DP6	11.0**	3.1	9.8	8.4	4.1	5.9	8.5	12.2	3.7	3.8	.8	1.5	1.5	.6
DG1[a]	.6	--	4.0	--	3.5	--	9.0	--	12.2	--	3.5	--	2.7	--
DG2	.6	.6	9.2**	1.5	1.4	1.8	16.9	23.8	23.6	20.5	3.4	3.8	1.3	.6
DG3	.6	.6	4.3**	1.4	1.2	1.5	12.8**	31.4	6.8	8.7	.8	.8	2.8	1.7
DG4	.6	.6	1.3	.7	2.7	2.3	41.3	24.7	6.7	9.0	3.6	1.3	1.9	.9
T1[a]	3.3	--	4.3	--	1.3	--	14.9	--	3.5	--	.9	--	2.1	--
T2[a]	.6	--	1.5	--	2.1	--	2.7	--	8.7	--	.6	--	.6	--
F prob.	<.01	<.01	>.1	<.01	<.01	<.05	<.01	<.1	<.01	>.1	<.05	<.05	<.01	<.05
$SE_{\bar{D}}$	1.4	.8	3.1	.6	.8	1.3	5.4	6.0	3.9	6.6	2.1	1.1	2.1	1.4
LSD	3.0	1.9	(6.7)	1.5	1.8	2.9	11.8	13.7	8.5	(13.9)	4.6	2.6	4.6	3.2

[a]Zones could not be sampled in 1972.

*Difference between years is significant at $p<0.10$.

**Difference between years is significant at $p<0.05$.

Isopods also occurred in the emergent phase close to shore at Rush Lake before the drawdown and at Trumbull Lake, but they were absent at the Dan Green sampling area 1. This discontinuous distribution is unexplained.

Physidae

Because of differences in the mean number of physid snails (mostly *Physa* spp.) at the two sampling sites of most sampling areas in 1971, the F-test for unequal snail numbers in different sampling areas was not significant ($p>0.10$) (Table 3). However, the largest populations tended to be in sampling areas with dense emergent vegetation (DP1 and DP6) or with both free-floating vegetation and dense submerged vegetation (DG2) (Table 3). At sampling area DP5, where there was floating vegetation and a moderate amount of submerged vegetation, physid snails browsed on underwater cattail stubble remaining from 1970. Numbers were lower in sampling areas where there were few floating plants (DP3, DP4, DG4, and T2). There was not much seasonal change except at sampling areas DP5 and DG2 where numbers increased greatly as the vegetative cover increased (Appendix A).

In 1972, physid snail numbers had decreased at open emergent phase sampling areas DP5 and DG2 as the floating cover decreased (Table 3). Numbers also decreased at sampling area DG3 where the coverage by submerged plants decreased. However, there was no decline at sampling area DP1, where the emergent cover decreased but the floating cover increased.

Planorbidae

Planorbid snails (*Gyraulus* spp.) also were more common in shallow water with emergent phase vegetation (DP1, DP5, DP6, and DG1) although they were not as numerous as physid snails (Table 3). Numbers of planorbid snails were low at sampling area T1 where the emergent vegetation was not as dense as in the other emergent phase sampling areas in shallow water and the sampling sites were farther from shore. Abundance tended to increase in shallow water areas between early and late June (Appendix A).

Amphipoda

Amphipods (predominantly Hyallela spp.) were the most abundant invertebrate taxa, and the open submergent phase sampling area DG4 had by far the greatest abundance in 1971 (Table 3). Amphipod numbers increased at most sampling areas between early and late June as the submerged vegetation grew (Appendix A).

At all sampling areas except DG4, there was an increase in the number of amphipods in 1972 (Table 3). This increase accompanied a general increase in the coverage of submerged plants and decrease in the coverage of emergent plants. Large increases in amphipod numbers occurred at sampling areas DG2 and DG3 where coontail became established in 1972 (Table 2). Concentrations of amphipods in coontail have also been reported by Andrews and Hasler (1944), Gerking (1957), and Arner, Norwood, and Teels (1970). An exception was found at sampling area DG4 where the numbers of amphipods decreased somewhat in 1972 although the coverage by coontail remained high. However, this coontail was not vigorous, was lying on the marsh bottom, and may have affected the amphipods.

Numbers of amphipods were fewest in the open submergent phase of Trumbull Lake (sampling area 2). Apparently, this diffuse stand of submerged clasping-leaf pondweed did not provide suitable habitat.

Chironomidae

Midges were most abundant at sampling areas DG2 (1971 and 1972), DP4 (1972), and DP5 (1972) (Table 3). All were open emergent or open submergent phase areas and were protected somewhat from the wind by nearby emergent vegetation. Sampling areas DP3, DG3, DG4, and T2 also had much submerged vegetation, but they were not so protected from the wind and midge numbers were lower. During 1971, midge data from the two sampling sites of the DG1 sampling area were very different, and the more open site 2 had the larger concentration (Appendix A).

Midge numbers were nearly constant during June except at sampling areas DG1 and T2 where they increased from very low numbers (Appendix A). At Trumbull Lake sampling area 2, the increase accompanied the growth of epiphytic algae which was used for cases.

Cladocera and Copepoda

The largest concentrations of both cladocera and copepods occurred in the protected open water phase at sampling area DP4 during late June, 1971 (Table 3). Both zooplankters decreased in abundance in 1972 as this sampling area gained submerged vegetation. During early June, 1971, they were also common at sampling area DG2, but as the submerged plants grew, zooplankton numbers declined (Appendix A). Large numbers of cladocera also occurred in the emergent phase at Rush Lake sampling area 1 during early June, 1970, in tiny, shallow openings in a stand of cattail.

Minor taxa

Only a few additional invertebrates occurred in numbers large enough that their abundance in different habitats could be measured (Table 4).

Caenid mayflies (Caenidae) had an abundance pattern very similar to amphipods. They were most abundant in dense submerged coontail (sampling area DG4) during 1971 when the plants were vigorous and were least common in the emergent and open water phases where submerged plants were few in number.

Odonata naiads exhibited a very uniform distribution except for a small concentration at sampling area DG2 in early June, 1971. However, preliminary samples taken with emergent insect traps indicated large concentrations of emerging odonates at sampling area DG4. Apparently, odonates from a large area were attracted to this artificial emergence site because of the very small amount of emergent vegetation in the sampling area. Because of this sampling bias, the use of emergent insect traps was discontinued.

Water boatmen (Corixidae) have been found to be quite abundant in several other studies (cf. Collias and Collias, 1963; Krull, 1970), but they were not common in this study. The maximum number recorded was 30 per .1 m^2 at sampling area DG2 in late June, 1972.

Lymnaeid snails (Lymnaea spp.) also are found in most marsh habitats. In this study, they were found to be almost nonexistent except for a very large concentration found at sampling area T1 in late June, 1971. The average abundance for this sampling area is actually the result of very high numbers of small individuals in two of the samples from one sampling site. The distribution of small lymnaeid snails must be very clumped, and

Table 4. Average number of selected invertebrates per .1 m^2

Sampling area	Sampling date	Phase	Taxa					
			Caenidae	Odonata	Corixidae	Ostracoda	Lymnaeidae	Sphaeriidae
DP1	1[a]	E	0	4	2	69	0	1
	2[b]	E	0	1	2	2	1	2
	3[c]	E	0	2	0	0	1	12
DP3	1	E	6	2	4	7	tr[d]	0
	2	E	1	2	2	0	tr	0
	3	OE	6	3	2	0	1	2
DP4	1	OW	0	tr	0	1	0	0
	2	OW	tr	1	1	tr	tr	0
	3	OS	7	2	2	0	0	22
DP5	1	E	17	1	1	3	tr	1
	2	E	3	2	1	0	1	3
	3	OE	14	3	3	0	0	15
DP6	1	E	6	3	tr	30	tr	10
	2	E	1	2	tr	0	tr	12
	3	E	tr	1	1	0	1	17
DG1	1	E	0	2	1	383	1	0
	2	E	0	1	3	13	1	0
DG2	1	OE	9	15	5	380	tr	0
	2	OE	2	5	3	2	tr	0
	3	OE	15	2	30	0	0	0
DG3	1	E	6	9	17	29	tr	0
	2	E	2	3	0	1	0	0
	3	OE	13	1	4	0	0	0

DG4	1	OS	53	3	1	1	0	0
	2	OS	76	2	6	0	0	0
	3	OS	11	1	8	0	0	0
T1	1	E	tr	1	0	24	3	tr
	2	E	0	tr	0	0	96	tr
T2	1	OS	3	tr	1	0	0	0
	2	OS	1	tr	0	0	tr	1

[a] Early June, 1971.

[b] Late June, 1971.

[c] Late June, 1972.

[d] Trace (<.50).

it is questionable if enough samples were taken to satisfactorily sample them.

Seed shrimp (Ostracoda) were present in the emergent phase and were very abundant in sampling areas DG1 and DG2 in early June, 1971. However, their numbers were greatly decreased by late June, 1971. They were not recorded at all in 1970 or 1972.

Fingernail clams (predominantly Sphaerium spp.) were present only in pothole A6 in Dewey's Pasture. Before 1972, they were common only in the bed of cattails that persisted through the drought of 1968 (sampling area DP6). They increased in this sampling area through the years and seemed to colonize other habitats from this remnant population.

Patterns of Benthos Abundance

Because of the very small size of the core sampler used (30 cm^2), numbers of organisms in the samples were few, and analysis of the data was difficult. However, a few trends were suggested from the samples taken in early June, 1971.

Abundance patterns of the more numerous benthic taxa (Appendix B) in most instances followed closely the abundance patterns of the phytomacrofauna (Appendix A) suggesting a close relationship between the benthos and the phytomacrofauna. A notable exception was the absence of benthic snails at Dan Green Slough and Trumbull Lake where free-swimming snails were present.

Very few invertebrates were present at Rush Lake in either the drawn down areas (R1 and R2) or the sampling area that remained flooded (R3) (Appendix B). However, a few soldier flies (Stratiomyidae) and flower flies (Syrphidae) persisted at sampling area R1, and a few punkies (Ceratopogonidae) were found in the exposed mud flat at sampling area R2.

Canonical Variate Analysis

Canonical variate analysis is a type of multivariate analysis used to study relationships among several sets of observations. When using canonical analysis, the original variates (sets of observations) are reduced by a mathematical transformation to a series of canonical variates. Each value in a canonical variate represents a mathematical transformation of the data from one set of observations, and they are determined so that each canonical variate emphasizes the difference between sets of observations. The first canonical variate accounts for the most variability, and each subsequently derived canonical variate accounts for a portion of the remaining variability.

The theoretical basis of this analytical technique has been thoroughly discussed by Seal (1964), Pielou (1969), and Tutsuoka (1971). However, canonical variate analysis has been used in biological studies by only a few researchers (cf. Jolicoeur, 1959; Buzas, 1967).

In the present study, the relationship between sampling areas was studied by plotting the canonical variates derived from the vegetation data against the canonical variates derived from the seven most numerous invertebrate taxa. The standard procedure, as described by Tutsuoka (1971), could not be used because of the small number of samples. Instead, the analysis was done indirectly by using the canonical variates initially derived from the vegetation data and the invertebrate data to construct new group canonical variates.

Although several vegetation group canonical variates and invertebrate group canonical variates were sequentially derived, only the first ones were used because they were the most highly correlated. Also, because of low invertebrate and/or plant abundance, canonical analysis was not used for data from early June and a few sampling areas in late June.

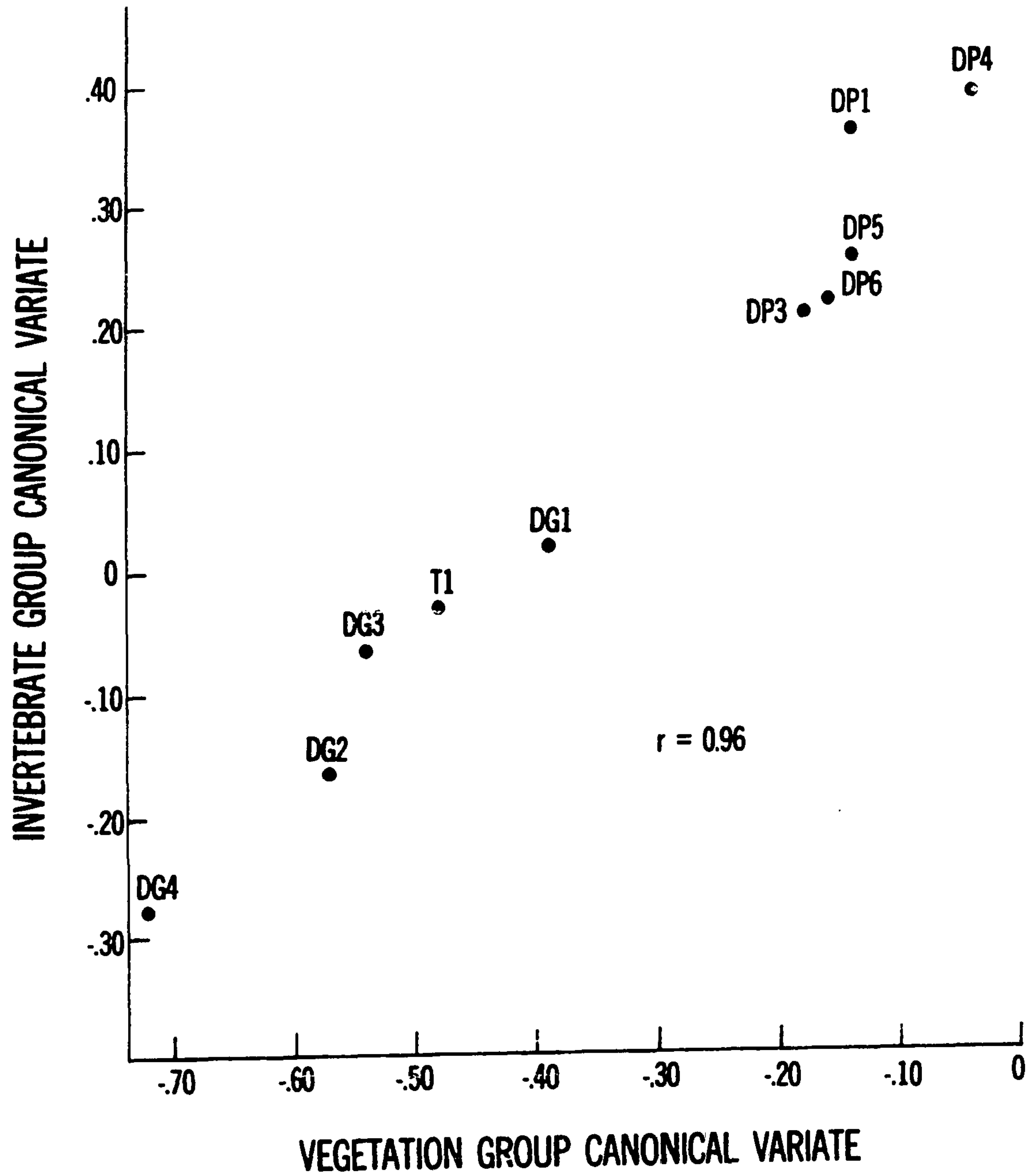
Late June, 1971

The relationship of different sampling areas is shown by plotting the group canonical variates (Figure 1), but the importance of the various plant and invertebrate taxa in this arrangement cannot be determined directly by the methods used. However, the high correlation (r = 0.96) indicates a close association between the vegetation and the invertebrates present in the various sampling areas. An examination of the basic data (Tables 2 and 3) provides an understanding of which plant and invertebrate taxa were important in the arrangement of the sampling areas.

The DP1 sampling area was characterized by having dense emergent vegetation which harbored isopods and the largest number of planorbid snails. The open water phase sampling area (DP4) also was separated from the other sampling areas (Figure 1) because of the lack of vegetation and the abundance of zooplankton.

Six sampling areas of the emergence phase were divided into two groups (Figure 1) because of the greater abundance of isopods at the Dewey's Pasture pothole and differences in the free-floating vegetation. Species present at the sampling areas in the Dewey's Pasture pothole (DP3, DP5, and DP6) were star duckweed and slender riccia. The other sampling areas (DG1, DG3, and T1) had only lesser duckweed and giant duckweed present.

Figure 1. A canonical analysis of marsh sampling areas using data from vegetation and seven invertebrate taxa (late June, 1971)


DP4
DP1
DP5
DP6
DP3
DG1
T1
DG3
DG2
DG4
r = 0.96
.40
.30
.20
.10
0
-.10
-.20
-.30
-.70
-.60
-.50
-.40
-.30
-.20
-.10
0
INVERTEBRATE GROUP CANONICAL VARIATE
VEGETATION GROUP CANONICAL VARIATE

The sampling area in the open emergent phase (DG2) differed from this large group by having more submergent vegetation, less emergent vegetation, and the most midges of any sampling area. Finally, the open submergent phase sampling area (DG4) was set apart also and had the most dense stand of coontail and the greatest concentration of amphipods.

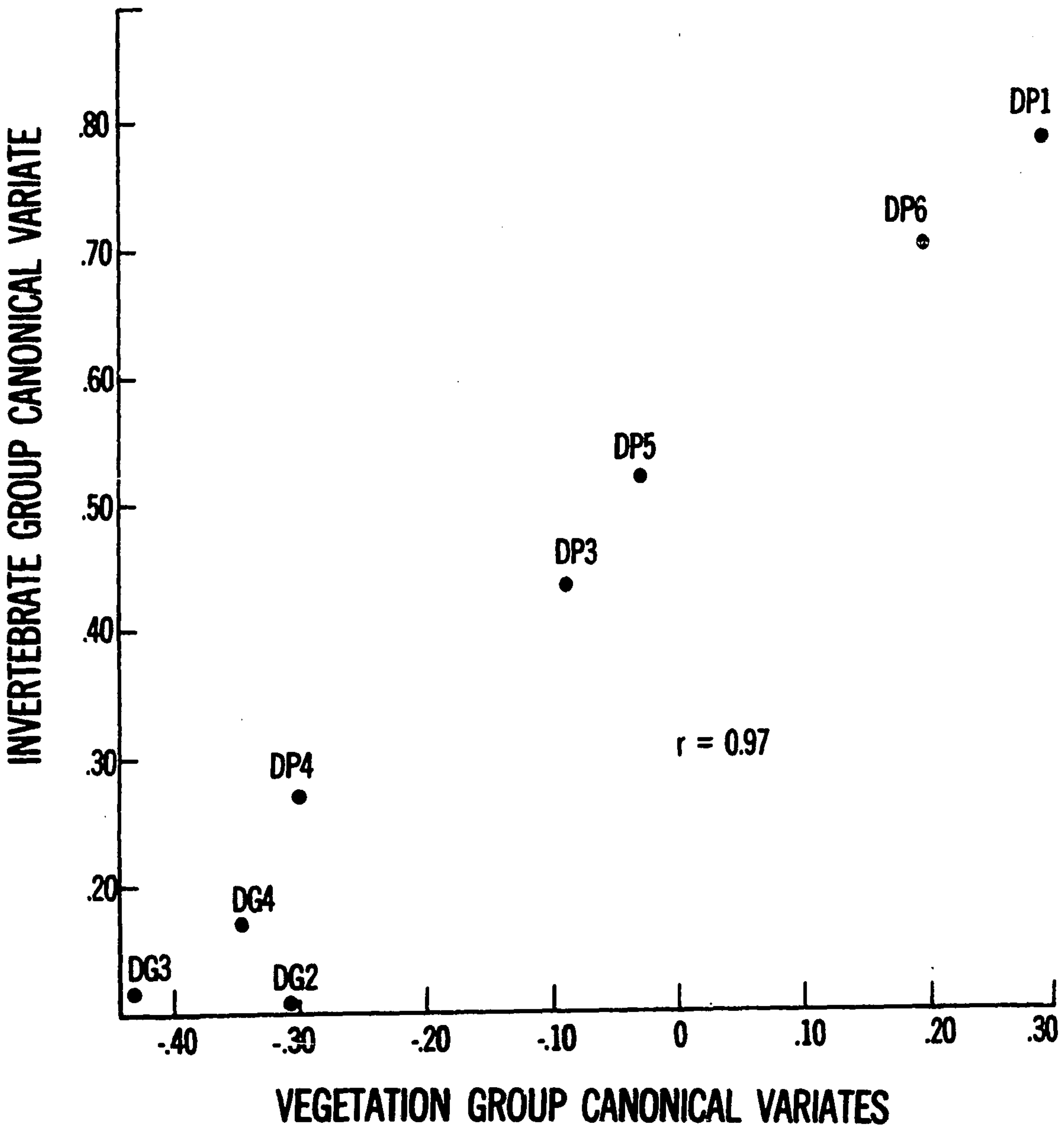
Late June, 1972

The eight areas sampled in 1972 were separated into three major groups by canonical variate analysis (Figure 2). The correlation between the vegetation group canonical variates and the invertebrate group canonical variates was 0.97.

Based on the data from Tables 2 and 3, sampling areas DP1 and DP6 were characterized by having emergent phase vegetation with star duckweed and slender riccia. They also had the most physid snails, and isopods were present. Sampling areas DP3 and DP5 were in the open emergent phase, and bladderwort was the dominant vegetation. Isopods were still present, but the reduced coverage by free-floating plants was not dense enough to permit large numbers of physid snails.

The remaining four sampling areas formed the most complex and interesting group. They were alike in many respects, but they also exhibited several differences. The DP4 sampling area was the only one without coontail, and it was the only sampling area without a large number of amphipods. Although the other sampling areas all produced large numbers of amphipods, the vegetation differed in each one. The DG4 sampling area was the only one without bladderwort, and sampling area DG3 was the only one with a dense coverage of duckweeds. Apparently, the presence of a moderate

Figure 2. A canonical analysis of marsh sampling areas using data from vegetation and seven invertebrate taxa (late June, 1972)


INVERTEBRATE GROUP CANONICAL VARIATE
.80
.70
.60
.50
.40
.30
.20
DP1
DP6
DP5
DP3
DP4
DG4
DG3
DG2
r = 0.97
-.40
-.30
-.20
-.10
0
.10
.20
.30
VEGETATION GROUP CANONICAL VARIATES

amount of bladderwort, with or without the presence of duckweeds, is not as important in determining amphipod abundance patterns as the presence of coontail.

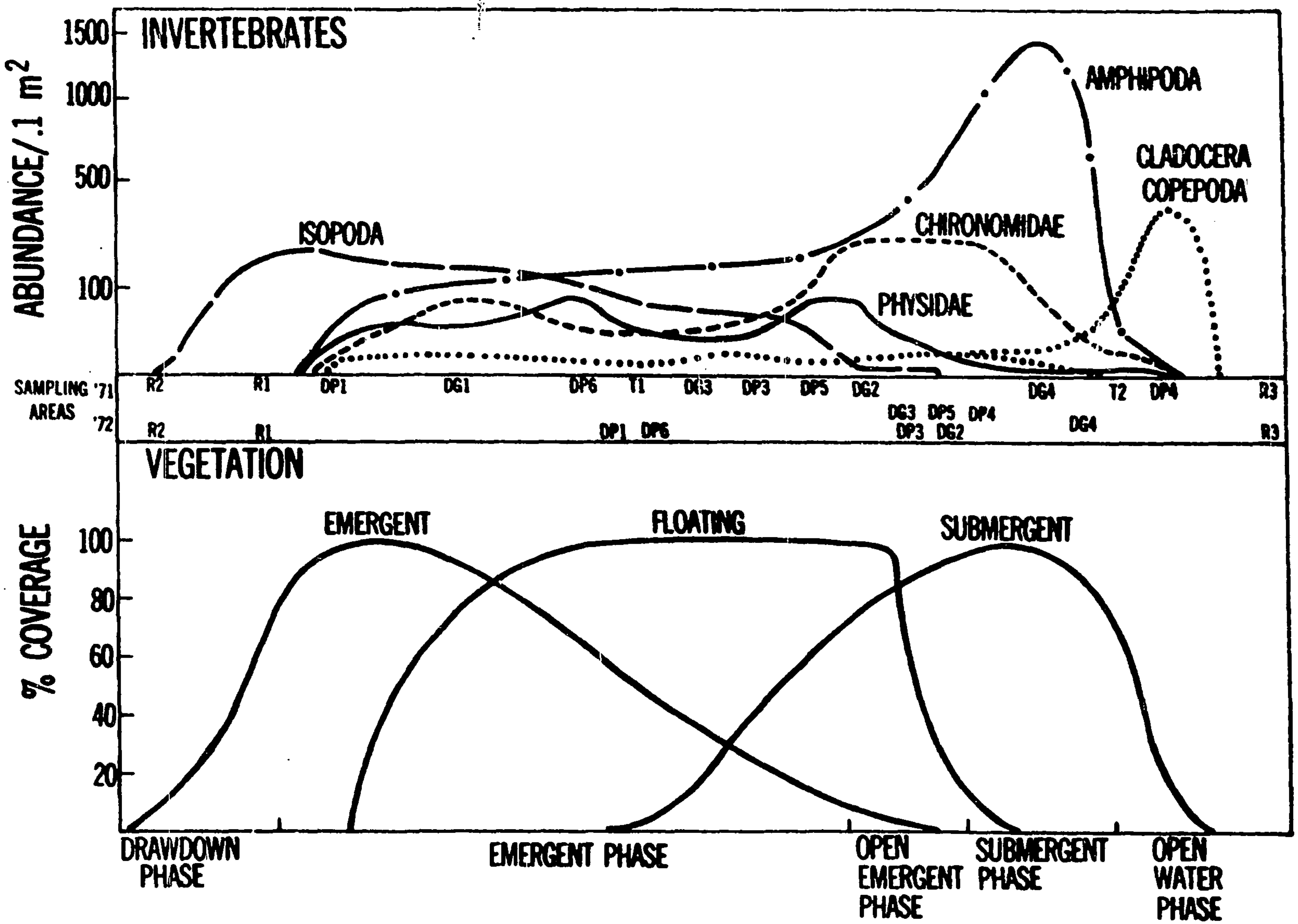
Patterns of Change in Invertebrate Abundance

The invertebrate-vegetation correlations and zone groupings determined by canonical variate analysis generally had ecological importance, but caution must be exercised when using this analysis alone. For example, it would seem that the presence of isopods was correlated with the distribution of star duckweed and slender riccia because those sampling areas where they occurred were grouped together (Figures 1 and 2). It is more likely that isopods were distributed independently and seemed to be associated with star duckweed and slender riccia only because of the relatively small number of habitats sampled.

To better understand the general patterns of vegetation and phytomacrofauna distributions, the sampling areas were arranged along a gradient of increasing openness of the habitat. The data then were plotted and curves fit by eye (Figure 3). Admittedly, considerable variation was smoothed over, but basic ecological patterns remain.

The most common invertebrates became established when dense emergent vegetation was flooded with shallow water, but most abundance peaks did not occur until the open emergent and open submergent phases when narrow-leafed submerged vegetation was providing substantial cover. Amphipods were the most abundant invertebrate taxa, and their peak abundance was reached when the submerged vegetation (coontail) was at peak abundance.

Figure 3. Generalized vegetation-phytomacrofauna associations along a gradient of natural vegetation change


INVERTEBRATES
ABUNDANCE/.1 m²
1500
1000
500
100
AMPHIPODA
CLADOCERA
COPEPODA
CHIRONOMIDAE
ISOPODA
PHYSIDAE
SAMPLING AREAS '71
R2 R1 DP1 DG1 DP6 T1 DG3 DP3 DP5 DG2 DG4 T2 DP4 R3
'72
R2 R1 DP1 DP6 DG3 DP5 DP4 DP3 DG2 DG4 R3
VEGETATION
% COVERAGE
100
80
60
40
20
EMERGENT
FLOATING
SUBMERGENT
DRAWDOWN PHASE
EMERGENT PHASE
OPEN EMERGENT PHASE
SUBMERGENT PHASE
OPEN WATER PHASE

Only the zooplankters were numerous in the open water phase. Their peak abundance was reached in quiet water with very little vegetation, but they were absent also in the windswept open water habitats.

Although the open emergent phase produced the most invertebrates, it is important that this phase be interspersed with the emergent phase for maximum production. Numbers of invertebrates were generally greater in sheltered areas near emergent vegetation, and some taxa, including physid snails and emerging odonates, were more common in the emergent phase.

DISCUSSION

Wetland areas with large invertebrate food supplies have been associated with increased use by breeding waterfowl. Wood duck (Aix sponsa) production in two Mississippi refuges was related to invertebrate production (Arner, Norwood, and Teels, 1970). In another study, several waterfowl species were so attracted to highly productive spring-fed salt marshes in Utah that they nested on dry land sites although their more typical over-water nesting sites were present on less productive marshes nearby (McKnight and Low, 1969).

Other marsh nesting birds are affected also by the production of invertebrate foods. Orians (1966) found that yellow-headed blackbirds (Xanthocephalus xanthocephalus) nesting in productive marshes in British Columbia had greater nesting success than those nesting in nearby less productive marshes. Also, diets of both yellow-headed blackbirds and red-winged blackbirds (Agelaius phoeniceus) changed from mostly aquatic insects during seasonal emergence peaks of odonates to an extensive use of terrestrial insects when odonate emergence rates declined at Rush Lake, Iowa (Voigts, 1973).

Because the largest number and greatest diversity of aquatic invertebrates seem to be produced when open habitats are interspersed with the emergent phase, this condition should attract the largest number and greatest diversity of nesting birds. Weller and Spatcher (1965) found that marshes characterized by emergent vegetation interspersed with open water (called hemi marsh) attracted more species and larger numbers of breeding birds. Although it is difficult to separate factors that attract breeding birds to a particular habitat, it is probable that hemi marsh is preferred for nesting because birds recognize and utilize the marsh habitat that produces optimal invertebrate supplies.

SUMMARY

The relationship between invertebrate populations and vegetative cover was studied in several Iowa marshes during the peak of the avian nesting season. Samples were taken at permanent sampling sites chosen at random within vegetation zones. Ecological phases were used to describe the continuous variable of vegetative change.

Although most taxa were present in all vegetated habitats, invertebrate populations responded to spatial and yearly changes in vegetation. A high correlation between the phytomacrofauna and the vegetation of the areas sampled was indicated by canonical variate analysis.

Shallow water with emergent and floating dead vegetation produced the most isopods, planorbid snails, and physid snails; physid snails had a second abundance peak in areas where submerged plants were found below dense free-floating plants.

In more open habitats which were somewhat protected from the wind, midges reached greatest abundance. Amphipods were the most numerous invertebrate taxa and were most abundant in dense beds of submerged vegetation.

Cladocera and copepods were most common in quiet open pools with little vegetation.

Total invertebrate abundance increased as the emergent vegetation was replaced by submergent vegetation, but maximum numbers seemed to occur where vegetated open habitats were interspersed with stands of emergents. It is suggested that nesting marsh birds are attracted to marshes that produce the most invertebrates.

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APPENDIX A: AVERAGE NUMBER OF FREE-SWIMMING INVERTEBRATES PER .1 m^2

Table A-1. Average number of free-swimming invertebrates per .1 m^2 in early June, 1971

Taxa	Sampling sites	DP1 1	DP1 2	DP3 1	DP3 2	DP4 1	DP4 2	DP5 1	DP5 2	DP6 1	DP6 2
Collembola											
Poduridae		0	0	0	0	0	0	0	0	0	0
Sminthuridae		0	0	0	0	0	0	0	0	0	tr
Ephemeroptera											
Caenidae		0	0	1	12	0	0	11	22	1	12
Baetidae		0	0	0	0	0	0	0	0	0	0
Odonata											
Aeshnidae		tr	2	2	2	tr	0	2	0	tr	2
Libellulidae		0	0	0	tr	0	0	0	0	0	tr
Lestidae		0	tr	0	tr	0	0	tr	tr	0	0
Coenagrionidae		3	3	0	0	0	0	tr	0	3	tr
Hemiptera											
Corixidae		0	1	1	7	0	0	0	2	0	1
Notonectidae		0	0	0	0	0	0	0	0	0	0
Pleidae		0	tr	1	0	0	0	1	0	0	tr
Gerridae		0	0	0	0	0	0	0	0	0	tr
Veliidae		1	tr	0	0	0	0	0	0	1	1
Mesoveliidae		0	tr	0	0	0	0	0	0	tr	tr
Lygaeidae		0	0	0	0	0	0	0	0	0	0
Neuroptera											
Corydalidae		0	0	0	0	0	0	0	0	0	0
Coleoptera											
Haliplidae		0	0	0	1	0	0	0	0	0	0
Dytiscidae		3	9	0	tr	tr	tr	2	5	2	4
Gyrinidae		0	0	0	0	0	0	0	0	0	tr
Hydrophylidae		2	1	tr	1	0	0	0	0	0	0
Staphylinidae		0	tr	0	0	0	0	0	0	0	0
Lampyridae		1	0	0	tr	0	0	tr	0	0	0
Helodidae		0	0	0	0	0	0	0	0	0	0
Coccinellidae		0	0	0	0	0	0	0	0	0	0
Curculionidae		tr	1	0	1	0	0	0	0	0	tr
Unidentified		tr	0	0	0	0	0	0	0	0	1
Tricoptera											
Phryganeidae		0	0	0	0	0	0	0	0	0	0
Limnephilidae		0	0	0	0	0	0	0	0	0	0
Leptoceridae		0	2	0	0	0	0	1	tr	0	1
Lepidoptera											
Pyralidae		0	0	0	0	0	0	0	0	0	0
Unidentified		tr	0	0	0	0	0	2	0	0	0

Sampling areas													
DG1		DG2		DG3		DG4		T1		T2		R3	
1	2	1	2	1	2	1	2	1	2	1	2	1	2
tr	-	tr	tr	4	4	0	0	1	tr	0	0	0	0
tr	tr	0	tr	0	0	0	0	0	0	0	0	0	0
0	0	14	3	4	8	8	99	tr	0	1	4	0	0
0	0	tr	0	0	0	0	tr	0	0	tr	0	0	0
0	1	7	2	1	2	0	0	0	1	0	0	0	0
tr	0	1	1	0	tr	0	0	0	0	0	0	0	0
0	1	3	3	3	tr	1	1	tr	tr	0	0	0	0
1	1	8	7	3	7	1	0	0	1	0	tr	0	0
0	3	6	4	30	3	tr	2	0	0	1	0	0	0
0	1	0	tr	1	tr	0	0	0	0	0	0	0	0
1	3	16	5	16	4	1	2	158	7	7	1	0	0
0	1	0	tr	0	1	0	0	0	tr	0	0	0	0
0	0	0	1	0	8	0	0	tr	0	0	0	0	0
0	0	2	2	1	15	0	0	0	0	0	0	0	0
0	0	0	tr	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	tr	0	0	0	0	0	0	0	0
0	tr	0	0	0	1	0	0	tr	1	0	0	0	0
3	tr	3	3	3	tr	tr	1	tr	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	tr	tr	1	0	1	0	0	0	1	0	0	0	0
0	0	0	0	0	tr	0	0	0	0	0	0	0	0
0	tr	0	0	0	tr	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	tr	0	0	0	0	0	0	0	0	0	0	0	0
1	1	tr	1	0	1	0	0	1	3	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	tr	1	3	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	tr	1	0	0	0
0	0	0	tr	0	0	0	0	0	0	0	0	0	0

Table A-1. (Continued)

Taxa	Sampling sites	DP1		DP3		DP4		DP5		DP6	
		1	2	1	2	1	2	1	2	1	2
Diptera											
Tipulidae		0	0	tr	tr	0	0	1	0	1	2
Chaoboridae		0	0	0	2	tr	tr	0	0	0	0
Culicidae		0	0	0	0	0	0	tr	0	0	0
Ceratopogonidae		1	1	2	5	0	0	5	11	0	2
Chironomidae		30	16	6	45	1	tr	29	10	20	48
Stratiomyidae		18	7	3	8	0	0	9	3	2	4
Tabanidae		0	0	0	0	0	0	0	0	0	0
Syrphidae		0	0	0	0	0	0	1	0	0	0
Sciomzidae		0	0	0	0	0	0	0	0	0	0
Unidentified		tr	0	0	0	0	0	0	0	0	0
Crustacea											
Cladocera		2	11	10	20	206	36	12	11	1	11
Chonchostraca		0	0	0	0	0	0	tr	0	0	0
Copepoda		0	6	2	6	5	3	1	2	2	25
Ostracoda		68	69	9	5	0	2	4	1	31	30
Amphipoda		22	35	12	47	1	1	26	29	33	124
Isopoda		47	45	1	7	0	0	1	105	87	333
Decapoda		0	0	0	0	0	0	0	0	0	0
Arachnida											
Acari		4	5	1	1	1	0	2	1	2	1
Araneida		1	tr	0	0	tr	0	tr	0	tr	0
Annelida											
Lumbriculidae		0	0	tr	1	0	0	1	1	tr	1
Hirudinea		8	4	0	5	0	0	2	2	1	5
Mollusca											
Physidae		53	62	10	34	tr	5	9	73	37	194
Planorbidae		5	8	3	8	1	2	6	7	9	3
Lymnaeidae		0	1	tr	1	0	0	tr	tr	0	1
Valvatidae		0	0	0	0	0	0	0	0	1	0
Sphaeriidae		0	1	0	0	0	0	0	2	6	16

Sampling areas													
DG1		DG2		DG3		DG4		T1		T2		R3	
1	2	1	2	1	2	1	2	1	2	1	2	1	2
tr	0	0	tr	tr	1	0	0	0	0	0	0	0	0
0	0	1	tr	0	0	0	0	0	0	0	0	0	0
0	0	2	0	0	0	0	0	0	0	0	0	0	0
2	0	3	4	4	2	4	1	0	0	0	0	0	0
28	31	287	465	74	96	73	37	7	27	tr	tr	0	0
1	3	1	8	3	2	1	0	5	10	0	0	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	tr	0	0	0	0	0
tr	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	tr	0	0	0	0
14	0	830	25	11	6	19	tr	0	0	0	0	0	0
0	tr	0	1	0	tr	0	0	0	0	0	0	0	0
14	4	5	31	5	17	7	14	2	4	1	0	0	0
656	110	515	244	2	57	1	1	0	47	0	0	0	0
29	25	62	140	23	133	47	43	27	11	0	0	0	0
0	0	0	0	0	0	0	0	0	13	0	0	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0
1	0	3	0	0	1	tr	tr	1	2	0	0	0	0
1	2	0	0	0	1	0	0	0	tr	0	0	0	0
tr	1	15	1	12	2	16	5	7	97	0	0	0	0
1	1	8	12	tr	3	1	0	tr	2	0	0	0	0
9	8	11	91	3	15	1	tr	2	26	1	0	0	0
4	0	0	1	0	1	1	0	tr	0	0	0	0	0
0	1	0	tr	0	tr	0	0	tr	6	0	0	0	0
0	0	0	0	0	0	0	0	0	0	4	11	0	0
0	0	0	0	0	0	0	0	0	tr	0	0	0	0

Table A-2. Average number of free-swimming invertebrates per .1 m^2 in late June, 1971

	Sampling areas									
	DP1		DP3		DP4		DP5		DP6	
Taxa / Sampling sites	1	2	1	2	1	2	1	2	1	2
Collembola										
Poduridae	tr	1	0	0	tr	0	0	0	tr	0
Sminthuridae	tr	0	0	0	0	0	0	0	0	tr
Ephemeroptera										
Caenidae	0	0	2	tr	tr	tr	4	2	0	1
Baetidae	0	0	0	0	0	0	0	0	0	0
Odonata										
Aeshnidae	1	tr	1	2	tr	0	4	tr	tr	2
Libellulidae	0	tr	0	0	0	tr	0	0	0	tr
Lestidae	tr	0	0	tr	tr	0	0	0	0	0
Coenagrionidae	0	0	1	0	0	0	0	0	0	0
Hemiptera										
Corixidae	2	2	2	1	0	1	tr	1	tr	0
Notonectidae	0	tr	1	tr	1	0	0	1	1	0
Pleidae	0	0	tr	1	0	0	4	5	0	1
Belostomatidae	0	0	0	0	0	0	0	0	0	0
Nepidae	0	0	0	0	0	0	0	0	0	0
Gerridae	0	tr	0	0	0	0	0	1	0	0
Veliidae	tr	tr	tr	tr	0	0	0	0	1	1
Mesoveliidae	1	0	0	tr	0	0	0	0	1	tr
Unidentified	0	tr	0	0	0	0	0	0	0	0
Coleoptera										
Carabidae	0	0	0	0	0	0	0	0	0	0
Haliplidae	tr	tr	tr	0	0	tr	tr	tr	tr	tr
Dytiscidae	3	6	1	2	0	0	2	1	1	1
Noteridae	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	0	tr	0	0	0	0
Hydrophylidae	0	tr	0	1	0	0	1	1	0	tr
Staphylinidae	0	0	0	0	0	0	0	0	0	0
Lampyridae	0	0	0	0	0	0	0	0	0	0
Helodidae	0	0	0	0	0	0	0	0	0	0
Chrysomellidae	0	tr	0	0	0	tr	0	0	tr	tr
Curculionidae	0	0	0	0	tr	tr	0	tr	0	0
Unidentified	0	tr	0	0	0	0	0	0	0	0
Tricoptera										
Phryganeidae	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	1	1	0	tr
Lepidoptera										
Pyralidae	0	0	0	0	0	0	tr	3	0	0
Unidentified	0	tr	0	0	0	0	0	0	0	0

Sampling areas													
DG1		DG2		DG3		DG4		T1		T2		R3	
1	2	1	2	1	2	1	2	1	2	1	2	1	2
7	6	0	0	2	1	0	0	0	0	0	0	0	0
tr	tr	0	0	0	0	0	0	0	0	0	0	0	0
0	0	3	1	3	2	120	29	0	0	0	1	0	0
0	0	0	0	0	0	1	tr	0	0	0	0	0	0
0	0	3	2	0	2	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	tr	0	0	0	0	0
0	0	2	2	3	1	2	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0	tr	0	0	0
4	2	1	4	0	0	6	5	0	0	0	tr	0	0
tr	3	0	tr	0	0	0	0	0	0	0	0	0	0
0	2	2	2	1	3	4	11	2	2	16	24	0	0
0	0	0	0	0	0	0	0	0	0	0	tr	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0
tr	0	0	0	0	0	0	0	0	0	0	0	0	0
1	tr	0	0	0	0	0	0	0	0	0	0	0	0
1	1	tr	0	0	tr	0	0	tr	0	0	0	0	0
0	tr	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0	tr	tr	0	tr	0	0
tr	1	1	1	tr	1	tr	1	0	1	0	tr	0	0
0	0	0	0	0	0	0	0	0	0	0	tr	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	2	3	0	0	0	0
tr	0	0	0	tr	0	0	0	0	0	0	0	0	0
0	0	0	0	tr	0	0	0	tr	0	0	0	0	0
0	0	0	0	tr	0	0	0	0	0	0	0	0	0
tr	0	0	0	tr	tr	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	16	15	0	0	0	0
0	0	0	0	0	tr	0	0	0	0	0	0	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	4	3	0	0	0	0	0	0
0	0	1	1	2	2	0	0	1	1	8	15	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-2. (Continued)

Taxa	Sampling sites	Sampling areas									
		DP1		DP3		DP4		DP5		DP6	
		1	2	1	2	1	2	1	2	1	2
Diptera											
Tipulidae		0	0	0	0	0	0	0	0	0	0
Chaoboridae		0	0	tr	1	1	0	0	0	0	0
Culicidae		0	0	0	tr	0	0	0	0	0	0
Ceratopogonidae		0	0	1	1	0	0	tr	0	0	1
Chironomidae		6	15	15	19	17	7	28	25	16	17
Stratiomyidae		3	5	1	7	1	0	7	5	1	2
Tabanidae		0	0	0	0	0	0	tr	0	0	0
Syrphidae		0	0	0	0	0	0	0	0	0	0
Unidentified		0	0	0	0	0	0	0	0	0	0
Crustacea											
Cladocera		6	7	11	23	39	219	0	2	1	0
Copepoda		11	8	156	8	504	279	5	23	1	3
Ostracoda		2	3	0	0	0	tr	0	0	0	0
Amphipoda		42	63	47	131	60	32	239	156	29	156
Isopoda		164	207	58	16	0	1	83	125	89	162
Arachnida											
Acari		1	1	0	tr	tr	6	0	0	0	0
Araneida		tr	tr	0	0	0	0	0	0	tr	0
Annelida											
Lumbriculidae		0	0	1	0	1	0	4	0	1	3
Hirudinea		tr	1	1	2	tr	tr	4	7	1	5
Mollusca											
Physidae		16	47	7	17	12	6	105	71	28	266
Planorbidae		31	66	12	6	4	1	83	83	24	22
Lymnaeidae		1	tr	0	1	tr	0	tr	1	0	1
Valvatidae		0	0	0	0	0	0	0	0	0	0
Sphaeriidae		1	3	0	0	0	0	tr	5	2	17

Sampling areas													
DG1		DG2		DG3		DG4		T1		T2		R3	
1	2	1	2	1	2	1	2	1	2	1	2	1	2
0	0	0	0	0	0	0	0	0	tr	0	0	0	0
0	1	tr	3	tr	tr	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	1	1	0	tr	tr	0	0	tr	0	0	0
18	51	469	710	31	74	64	33	9	19	38	134	0	0
3	1	3	2	1	tr	0	1	tr	1	0	0	0	0
0	0	0	tr	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	tr	0	0	0	0	0
tr	0	0	0	0	0	0	0	0	0	0	0	0	0
12	14	19	8	tr	tr	3	31	0	1	0	0	0	0
10	7	3	1	9	7	tr	9	5	8	0	0	0	0
19	9	3	1	0	2	0	0	0	0	0	0	0	0
87	78	313	265	131	201	927	3772	342	150	7	8	0	0
0	0	0	0	0	0	0	0	1	36	0	0	0	0
0	tr	1	2	0	tr	1	5	0	0	1	1	0	0
0	1	0	0	0	tr	0	0	0	0	0	0	0	0
1	7	13	6	0	0	0	0	3	43	6	35	0	0
2	4	28	11	10	10	2	1	1	3	0	0	0	0
12	21	29	169	17	21	1	1	0	69	1	3	0	0
22	1	3	2	tr	3	7	7	tr	4	2	8	0	0
2	tr	1	0	0	0	0	0	4	190	0	1	0	0
0	0	0	0	0	0	0	0	0	0	7	3	0	0
0	0	0	0	0	0	0	0	0	tr	2	0	0	0

Table A-3. Average number of free-swimming invertebrates per .1 m^2 in late June, 1972

Taxa	Sampling sites	DP1 1	DP1 2	DP3 1	DP3 2	DP4 1	DP4 2	DP5 1	DP5 2
Collembola									
Poduridae		0	0	0	0	0	0	0	0
Sminthuridae		0	tr	0	0	0	0	0	0
Ephemeroptera									
Caenidae		0	0	6	5	4	11	14	13
Baetidae		0	0	0	0	0	0	0	0
Odonata									
Aeshnidae		1	1	2	2	1	3	3	2
Libellulidae		tr	tr	tr	0	tr	0	1	0
Lestidae		0	tr	1	0	0	0	0	0
Coenagrionidae		tr	0	0	0	0	tr	0	0
Hemiptera									
Corixidae		0	0	3	1	1	3	2	4
Notonectidae		0	0	2	tr	1	1	2	1
Pleidae		2	tr	9	4	2	1	4	tr
Belostomatidae		tr	0	0	0	tr	0	0	0
Nepidae		0	0	0	0	0	0	0	0
Gerridae		1	1	0	tr	0	0	0	0
Veliidae		3	tr	0	0	0	0	0	0
Mesoveliidae		2	tr	0	tr	0	0	0	0
Coleoptera									
Haliplidae		0	1	0	tr	1	tr	7	2
Dytiscidae		5	10	1	1	tr	tr	0	tr
Hydrophylidae		1	2	0	0	0	0	0	0
Lampyridae		0	0	0	0	0	0	0	0
Helodidae		0	tr	0	0	0	0	0	0
Chrysomelidae		0	0	0	0	0	0	0	0
Tricoptera									
Psychomyiidae		0	0	0	0	0	0	0	0
Limnephilida		0	0	0	0	0	0	0	0
Leptoceridae		0	0	2	1	tr	0	tr	tr
Lepidoptera									
Pyralidae		tr	2	0	1	0	tr	0	tr
Diptera									
Tipulidae		tr	0	0	0	0	0	0	0
Chaoboridae		0	0	1	tr	0	tr	0	0
Culicidae		0	5	0	0	0	0	0	0
Ceratopogonidae		tr	1	9	3	5	2	9	12
Chironomidae		8	80	49	41	188	692	214	115
Stratiomyidae		tr	1	tr	2	0	0	1	tr
Sciomzidae		tr	0	0	0	0	0	0	0
Ephydridae		0	0	1	0	0	0	2	0

Sampling areas									
DP6		DG2		DG3		DG4		R3	
1	2	1	2	1	2	1	2	1	2
0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1	0	5	25	19	8	23	9	0	0
0	0	0	0	0	0	1	0	0	0
tr	2	0	2	1	1	2	0	0	0
0	tr	0	1	0	0	0	0	0	0
0	0	0	0	0	0	tr	0	0	0
0	0	0	1	1	0	tr	0	0	0
1	0	18	42	tr	7	4	13	0	0
0	0	1	2	0	4	1	0	0	0
5	12	11	1	31	88	6	7	0	0
0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	tr	0	0	0	0
1	1	0	0	0	0	0	0	0	0
16	11	0	0	tr	0	0	0	0	0
1	tr	0	1	2	2	0	0	0	0
0	1	4	22	tr	1	1	0	0	0
3	2	tr	1	tr	1	1	tr	0	0
tr	0	tr	tr	0	tr	0	0	0	0
0	tr	0	0	0	0	0	0	0	0
0	tr	0	0	0	0	0	0	0	0
0	0	0	0	tr	0	0	0	0	0
0	0	0	0	tr	0	0	0	0	0
0	0	0	tr	0	0	0	0	0	0
tr	0	1	1	2	tr	5	2	0	0
1	tr	0	tr	7	3	2	0	0	0
1	1	0	0	tr	0	0	0	0	0
0	0	0	0	0	0	tr	0	0	0
0	2	0	0	0	0	0	0	0	0
0	2	7	6	9	4	14	11	0	0
17	15	106	979	49	122	142	39	0	0
1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	tr	0	0	0	0	0

Table A-3. (Continued)

Taxa	Sampling sites	DP1		DP3		DP4		DP5	
		1	2	1	2	1	2	1	2
Crustacea									
Cladocera		tr	1	6	2	17	35	10	13
Copepoda		1	tr	57	3	49	26	9	13
Amphipoda		135	240	313	323	156	132	625	321
Isopoda		18	15	18	14	2	3	7	6
Decapoda		0	0	0	0	tr	0	0	0
Arachnida									
Acari		0	0	2	0	1	1	tr	0
Araneida		2	0	0	tr	0	0	0	0
Annelida									
Lumbriculidae		1	11	5	6	12	3	1	11
Hirudinea		3	17	5	6	3	1	3	7
Mollusca									
Physidae		67	72	16	19	8	12	26	8
Planorbidae		10	54	6	3	11	14	41	20
Lymnaeidae		tr	1	tr	1	0	0	0	0
Valvatidae		tr	0	0	0	0	0	0	0
Sphaeriidae		9	16	4	tr	26	17	11	19

Sampling areas									
DP6		DG2		DG3		DG4		R3	
1	2	1	2	1	2	1	2	1	2
3	1	4	52	tr	tr	1	2	0	0
0	0	0	0	1	1	1	0	0	0
168	138	2662	293	1562	621	897	405	0	0
6	16	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	tr	3	1	tr	2	tr	1	0	0
0	0	0	0	0	0	0	0	0	0
5	8	7	17	14	7	1	0	0	0
2	3	6	11	22	6	5	1	0	0
70	81	2	3	2	2	0	tr	0	0
50	27	1	8	1	4	4	6	0	0
1	tr	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
3	30	0	0	0	0	0	0	0	0

APPENDIX B: AVERAGE NUMBER OF BENTHIC INVERTEBRATES PER 30 cm^2

Table B-1. Average number of benthic invertebrates per 30 cm^2 in early June, 1971

Taxa	DP1 1	DP1 2	DP3 1	DP3 2	DP4 1	DP4 2	DP5 1	DP5 2	DP6 1	DP6 2	DG1 1	DG1 2
Ephemeroptera												
Caenidae	0	0	tr	2	tr	0	3	3	0	1	0	0
Odonata												
Aeshnidae	0	0	tr	tr	0	0	0	0	0	0	0	0
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	0
Coenagrionidae	tr	0	0	tr	0	0	0	0	0	tr	0	tr
Hemiptera												
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera												
Carabidae	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	tr	0	0	0	0	0	tr	0	0	0	0	0
Hydrophylidae	0	0	0	0	0	0	tr	0	0	0	0	0
Lampyridae	tr	0	0	0	0	0	0	0	0	0	0	0
Tricoptera												
Psychomyiidae	0	0	0	0	0	0	0	0	0	0	0	0
Diptera												
Tipulidae	0	0	0	0	0	0	0	0	0	tr	0	0
Chaoboridae	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	1	0	tr	0	0
Chironomidae	2	2	4	5	1	1	5	2	1	2	0	2
Stratiomyidae	0	tr	tr	tr	0	0	tr	0	tr	1	tr	0
Tabanidae	0	0	0	1	0	tr	0	0	0	0	0	0
Syrphidae	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified	0	tr	0	1	0	0	0	0	0	1	0	0
Crustacea												
Cladocera	0	0	4	0	1	0	1	0	0	0	0	0
Copepoda	0	0	1	0	0	0	0	0	0	0	0	0
Ostracod	2	1	0	0	2	0	tr	0	0	0	0	0
Amphipoda	2	3	1	2	2	0	1	1	tr	2	1	0
Isopoda	3	tr	tr	0	0	0	2	3	1	3	0	0
Arachnida												
Acari	tr	tr	tr	0	1	0	tr	0	0	0	0	1
Araneidea	0	0	0	0	0	0	0	0	0	0	0	0
Annelida												
Lumbriculidae	0	0	6	9	7	9	1	1	2	0	1	0
Hirudinea	tr	0	tr	0	0	0	0	tr	0	0	0	tr
Mollusca												
Physidae	1	1	1	2	0	1	1	1	tr	1	0	0
Planorbidae	1	2	2	3	2	1	2	tr	tr	tr	0	0
Sphaeriidae	0	0	0	0	0	0	0	1	1	1	0	0

Sampling areas															
DG2		DG3		DG4		T1		T2		R1		R2		R3	
1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
tr	0	0	tr	2	15	tr	0	0	2	0	0	0	0	0	0
tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0
tr	0	0	tr	tr	1	0	0	0	0	0	0	0	0	0	0
tr	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	tr	0	0	2	0	tr	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	tr	0	0	0	0	0
tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	tr	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	tr	1	1	0	0
tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
tr	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0
tr	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0
24	11	8	10	2	7	1	1	5	5	0	0	0	tr	tr	0
0	tr	0	0	0	0	0	tr	0	0	1	1	0	0	0	0
0	0	0	0	0	0	0	tr	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	tr	0	0	0	0
tr	1	tr	0	0	1	1	1	0	1	0	0	0	0	0	0
0	0	0	0	0	tr	0	0	0	0	0	0	0	0	0	0
0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	4	8	2	0	0	1	tr	0	0	0	0	0	0	0
0	tr	0	tr	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	tr	0	0	0	0
1	1	tr	3	0	1	1	7	8	2	1	0	0	0	0	0
1	0	1	tr	0	0	0	0	tr	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0